THE PROGRESS OF THE HENRY DRAPER MEMORIAL.[1]

THE additional facilities provided by Mrs. Draper have permitted a considerable extension of this research during the past year. The 11-inch refractor belonging to Dr. Draper, and the 8-inch photographic telescope provided by the Bache Fund, have been kept at work throughout every clear night. The 28-inch and 15-inch reflectors constructed by Dr. Draper have been moved to Cambridge, and the first of these instruments is placed in a building surmounted by a dome constructed for the purpose. Experiments are now in progress with it, and it will probably soon be employed regularly. Four assistants take part in making the photographs, one of whom comes to the Observatory every clear night about midnight, and keeps the 8-inch and 11-inch telescopes in use until interrupted by the morning twilight. Five ladies have been employed in the measurements and reductions.

The various investigations now in progress are described in detail below. The first three of these, including the photographic work of the 8-inch and 11-inch telescopes, will be finished in about a year. It is accordingly proposed in the autumn of 1889 to send an expedition to the southern hemisphere, probably to Peru, and there complete the work to the South Pole. As only about one quarter part of the sky is too far south to be conveniently observed at Cambridge, it is expected that the photographs needed to cover this portion of the sky could be obtained in two years. Each investigation could thus be extended to all parts of the sky upon the same system.

An important advance has been made by the recent improvements in the manufacture of dry plates. The M. A. Seed Company of St. Louis have endeavoured to comply with our request for more sensitive plates, and have gradually increased their sensitiveness, so that they now furnish us with plates measuring 27 on their scale, while a year ago the most sensitive plates were only numbered 21. As a result, stars nearly a magnitude fainter can be photographed, and the number of objects which can be examined is nearly doubled. A careful study will shortly be made, by the help of the instruments described below, of the most sensitive plates obtainable. It is hoped that makers of very sensitive plates will send specimens to Cambridge for trial. The demand for increased sensitiveness is so great not only here, but at all other observatories where stellar photography is carried on, that a real improvement would be widely appreciated.

Various improvements have been made in the methods of detecting defects in the photographic processes. Each plate, when it is taken from its box, is exposed to a standard light for exactly one second. The portion of the flame of an oil lamp shining through a small circular aperture constitutes the standard light. The exposure is made for a second by means of a pendulum, which allows the light to shine on the plate for this interval through a small square aperture. When the plate is developed, a dark square appears near its edge, whose intensity measures the sensitiveness of the plate, and also serves to detect any defect in its development. Passing clouds, or a variation in the clearness of the sky, are detected by an instrument called the Pole-Star recorder. It consists of a telescope with a focal length of about 3 feet, placed parallel to the earth's axis. An image of the Pole-Star is formed by it, and allowed to fall upon a sensitive plate, describing an arc of a circle, which is interrupted whenever clouds pass. The plate is changed every day, and the instrument is closed automatically by an alarm-clock every morning before the twilight begins. Much trouble is experienced from the deposition of moisture on the objectives of the photographic telescopes, on account of their exposure to a large portion of the sky. The failure of some of the earlier plates may be due to this cause. Moisture is now carefully looked for, and, if detected, removed by gently heating the objectives. Another test of the quality of the plates consists in occasionally exposing a plate in the 8-inch telescope to the circumpolar sky, first with and then without the prism. The trails of the stars near the Pole and the spectra of the brighter stars are thus photographed. A comparison of the intensity of these images tests the condition of the air, the instrument, and the plates.

The various investigations will now be described in order, as in the last Report.

1. *Catalogue of Spectra of Bright Stars.*—The spectra of all the brighter stars have been photographed with the 8-inch telescope, giving an exposure of at least five minutes to each. Each plate contains from two to four regions 10° square. The plates representing the region north of − 25° were divided into three series, which may be distinguished as polar, zenith, and equatorial. Each region is contained on two plates, and the work has been repeated in two successive years, so that at least four photographs should be obtained of all the brighter stars. If a plate proved poor, it was repeated, so that the very bright stars will appear in several plates. The photographic portion of this work was finished last November. If no plates had been repeated, 36 polar, 72 zenith, and 72 equatorial plates would have been required each year, or 360 in all. The actual numbers of plates taken and measured were 46, 120, and 93, total 259, the first year; and 61, 209, and 104, total 374, the second year; or 633 in all. In the later work the number of zenith plates was doubled, to avoid the confusion arising when several exposures were made on a single plate. The numbers of spectra measured on these plates were 2381, 3314, and 2618, total 8313, the first year; and 7199, 8217, and 4074, total 19,490, the second year. Two plates covering the immediate vicinity of the North Pole contain 150 spectra. The whole number of spectra is therefore 27,953. The measurement and identification of this large number of spectra has occupied the greater portion of the time of the corps of computers. Each plate to be measured was placed on a stand, and the light of the sky was reflected through it by means of a mirror. The approximate coordinates of each spectrum in turn were then read off, and a careful description of the spectrum was given. Besides the usual division into types, each additional line visible was recorded both as regards its position and intensity. The photographic intensity of the brightest portion of each spectrum was also measured by means of a photographic plate, dark at one end and light at the other, like a wedge of shade glass. When the spectra show sudden changes in brightness, additional measurements are made. This portion of the work is complete only for the polar plates and about 62 of the other plates, including 12,574 spectra. The identification of the spectra is effected either by computation from its co-ordinates, or by laying the plate upon the maps of the "Durchmusterung," the scale being the same for both. All the plates have, however, been checked by the latter method. The names of the stars are then taken from the "Harvard Photometry," "Uranometria Argentina," or "Durchmusterung," according to their brightness and declination. Their places are next brought forward to 1900, the epoch of the final catalogue. As the intensity of the photograph of a given spectrum will vary greatly with the sensitiveness of the plate, the clearness of the air, and the rate of the driving-clock, all must be reduced to the same system. The scale of the "Harvard Photometry" is adopted for this purpose. The most prevalent spectra are those of the first type, in which the K line is too faint to be visible. After applying a correction for the declination of the stars, the brightness of all such spectra on each plate is compared with the photometric magnitudes. A correction is thus derived for each plate, which is applied to all the spectra upon it. The effect of colour, so far as it varies with the type of spectrum, is thus eliminated. It is possible that, owing to variations in temperature, or other causes, some stars may be redder or bluer than others having the same type of spectrum.

2. *Catalogue of Spectra of Faint Stars.*—Until the photographs required for the research mentioned above were completed, the time of the 8-inch telescope was mainly devoted to them. Since then it has been used principally in photographing the fainter stars. An exposure of one hour is given to each portion of the sky, a region 10° square being included upon each plate. Stars as far south as − 25° can be advantageously photographed at Cambridge, and the plan proposed covers this region. The plates overlap, so that the region north of − 20° will appear on at least two plates. The southern stars are only photographed when the sky is unusually clear. Each plate is examined, and, if unsatisfactory, the work is repeated. If all were good, 650 plates would be required. Thus far, 606 plates have been taken, covering 339 of the desired regions. As the time of the computers has been mainly devoted to the first investigation mentioned above, the greater portion of these plates have not been measured or reduced. The total number measured is 105 plates, containing 6931 spectra, of which 94 plates and 6293 spectra

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[1] Extracted from the "Second Annual Report of the Photographic Study of Stellar Spectra conducted at the Harvard College Observatory," Edward C. Pickering, Director. With 2 Plates. (Cambridge: John Wilson and Son, University Press, 1888.)

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have been reduced. The form of reduction and publication will be similar to the catalogue of bright stars, except that it will be convenient to retain the "Durchmusterung" numbers and places, arranging the stars in the order of the zones in that catalogue. It is hoped that the photographs for this investigation will be nearly all taken by the autumn of 1888, and the remainder during the following year. To provide for a possible increase in sensitiveness of the plates, precedence is given to those completely covering the sky once, the alternate plates, covering the sky the second time, being taken later. The actual improvement in the plates shows itself by an increase in the number of spectra in this second series of plates. In some cases over three hundred stellar spectra appear on a single plate.

3. *Detailed Study of the Spectra of the Brighter Stars.*—These spectra are obtained by placing four prisms, having an angle of about 15°, and each nearly a foot square, over the object-glass of the 11-inch telescope, as described in the last Report. The increased sensitiveness of the plates has greatly increased the number of stars bright enough to produce a satisfactory image in this way. The white stars of the first type give good images when no brighter than the fourth magnitude. These spectra are about 4 inches in length. An improvement has been made in the method of enlargement with a cylindrical lens described in the last Report. When such a lens was used with an enlarging lens having a small aperture, the width of the spectrum was greatly reduced; with a large aperture, the best definition could not be attained. A slit perpendicular to the axis of the cylindrical lens is accordingly placed over it.. This reduces the aperture in one direction so that the definition of the lines is good, without affecting the width of the spectrum. Slow plates are also used in the enlargements to increase the contrast. Much more brilliant spectra are thus obtained.

4. *Faint Stellar Spectra.*—As stated above, the 28-inch reflector constructed by Dr. Draper is now ready for use. The difficulties commonly encountered in the use of a large reflector have been met, and it is hoped successfully overcome. A spectroscope has been devised for this instrument which will give a dispersion about equal to that employed in the first and second of the researches described above. As the area of the aperture of this telescope is about eleven times that of the 8-inch telescope, it is hoped that much fainter stars can be photographed with it. A study will be made of the spectra of the variable stars of long period, of the banded stars, and of other objects having peculiar spectra.

But little progress has been made with the other investigations proposed, including the reduction to wave-lengths, and the study of the approach and recession of the stars. It seemed best to concentrate our work on the researches described above, undertaking the other investigations as soon as time permitted.

The investigations described above are illustrated by a plate. A special study was made of the spectrum of the variable star β Persei. A variation in this spectrum would have an important bearing on the theory that the diminution in light is due to an interposed dark satellite. Spectra of this star at minimum were first obtained with one prism. With the increased sensitiveness of the plates more prisms were tried, until finally good spectra were obtained with all four prisms even when the star was at its minimum. At first it was thought that a variation was detected in the spectrum, but this change was not confirmed under more favourable circumstances. The spectrum of this star on February 6, 1888, when at its full brightness, is contrasted in the plate with the spectrum on February 9, 1888, when the star was at its minimum. A careful inspection of the original negatives failed to show any differences in the spectra. Twenty lines are visible at minimum, all of which are seen at maximum. The spectrum of α Orionis is also given. Before the recent increase in the sensitiveness of the photographic plates, satisfactory photographs could not be obtained of the spectrum of this star, on account of its red colour.

INFLUENCE MACHINES.[1]

I HAVE the honour this evening of addressing a few remarks to you upon the subject of influence machines; and the manner in which I propose to treat the subject is to state as shortly as possible, first, the historical portion, and afterwards to point out the prominent characteristics of the later and the more commonly known machines.

In 1762, Wilcke described a simple apparatus which produced electrical charges by influence, or induction, and following this the great Italian man of science, Alexander Volta, in 1775 gave the electrophorus the form which it retains to the present day. This apparatus may be viewed as containing the germ of the principle of all influence machines yet constructed.

Another step in the development was the invention of the doubler by Bennet in 1786. He constructed metal plates which were thickly varnished, and were supported by insulating handles, and which were manipulated so as to increase a small initial charge. It may be better for me to here explain the process of building up an increased charge by electrical influence, for the same principle holds in all of the many forms of influence machines.

This Volta electrophorus, and these three blackboards, will serve for the purpose. I first excite the electrophorus in the usual manner, and you see that it then influences a charge in its top plate; the charge in the resinous compound is known as negative, while the charge induced in its top plate is known as positive. I now show you by this electroscope, that these charges are unlike in character. Both charges are, however, small, and Bennet used the following system to increase them.

Let these three boards represent Bennet's three plates. To plate No. 1 he imparted a positive charge, and with it he induced a negative charge in plate No. 2. Then with plate No. 2 he induced a positive charge in plate No. 3. He then placed the plates Nos. 1 and 3 together, by which combination he had two positive charges within practically the same space, and with these two charges he induced a double charge in plate No. 2. This process was continued until the desired degree of increase was obtained. I will not go through the process of actually building up a charge by such means, for it would take more time than I can spare.

In 1787, Carvallo discovered the very important fact that metal plates when insulated always acquire slight charges of electricity; following up those two important discoveries of Bennet and Carvallo, Nicholson in 1788 constructed an apparatus, having two disks of metal insulated and fixed in the same plane. Then, by means of a spindle and handle, a third disk, also insulated, was made to revolve near to the two fixed disks, metallic touches being fixed in suitable positions. With this apparatus he found that small residual charges might readily be increased. It is in this simple apparatus that we have the parent of influence machines, and as it is now a hundred years since Nicholson described this machine in the Phil. Trans., I think it well worth showing a large-sized Nicholson machine at work to-night.

In 1823, Ronalds described a machine in which the moving disk was attached to and worked by the pendulum of a clock. It was a modification of Nicholson's doubler, and he used it to supply electricity for telegraph working. For some years after these machines were invented no important advance appears to have been made, and I think this may be attributed to the great discoveries in galvanic electricity which were made about the commencement of this century by Galvani and Volta, followed in 1831 to 1857 by the magnificent discoveries of Faraday in electro-magnetism, electro chemistry, and electro-optics, and no real improvement was made in influence machines till 1860, in which year Varley patented a new form of machine.

In 1865 the subject was taken up with vigour in Germany by Toepler, Holtz, and other eminent men. In 1866, Bertsch invented a machine, but not of the multiplying type; and in 1867, Sir William Thomson invented a form of machine, which, for the purpose of maintaining a constant potential in a Leyden jar, is exceedingly useful.

The Carré machine was invented in 1868, and in 1880 the Voss machine was introduced, since which time the latter has found a place in many laboratories. It closely resembles the Varley machine in appearance, and the Toepler machine in construction.

In condensing this part of my subject, I have had to omit many prominent names and much interesting subject-matter, but I must state that, in placing what I have before you, many of my scientific friends have been ready to help and to contribute; and, as an instance of this, I may mention that Prof. Silvanus P. Thompson at once placed all his literature and even his private notes of reference at my service.

I will now endeavour to point out the more prominent features

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[1] Lecture delivered at the Royal Institution, by Mr. J. Wimshurst, on April 27, 1888.

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